Network Time Synchronization Servers at the U. S. Naval Observatory

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Abstract

Responding to an increased demand for reliable, accurate time on the Internet and Milnet, the U.S. Naval Observatory Time Service has establ;ished the network time servers, tick.usno.navy.mil *and* tock.usno.navy.mil*. The system clocks of these HP9000/747i industrial work stations are synchronized to within a few tens of microseconds of USNO Master Clock 2 using VMEbus IRIG-B interfaces. Redundant time code is available from a VMEbus GPS receiver.*

UTC(USNO) is provided over the network via a number of protocols, inculding the Network Time Protocol (NTP) [DARPA Network Working Group Report RFC-1305], the Daytime Protocol [RFC-867], and the Time protocol [RFC-868]. Access to USNO network time services is presently open and unrestricted.

An overview of USNO time sevices and results of LAN and WAN time synchronization tests will be presented.

In October, 1994, the Internet consisted of 3,864,000 hosts in 56,000 domains over 37,022 networks. This represents a growth rate in number of hosts of 61% over 12 months[1]. A number of networked time servers are providing time to this population voluntarily, using the Network Time Protocol (NTP) and other protocols, but the top of the timing pyramid, the domain of the stratum-1 servers, is sparsely populated. The current list of primary servers[2] includes:

Time Synchronization Source

Region	Atomic	GPS	WWV/DCF77	GOES	Other
US West	-	1	8	1	
US Mountain	2	-	1	-	
US Midwest	-	-	3	-	
US East	2	2	6	-	
Hawaii	-	-	1	-	
Canada	-	-	-	2	
Japan	-	4	-	-	
France	-	-	1	-	
Germany	-	1	3	-	
Australia	1	-	-	-	1 Omega
United Kingdom	-	-	2	-	
Netherlands	-	-	1	-	
Switzerland	-	-	1	-	
Norway	1	1	1	-	1 Loran-C

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The two U.S. East servers with atomic clock links are new additions, the USNO network time servers tick.usno.navy.mil and tock.usno.navy.mil. They are Hewlett–Packard HP9000/747i industrial VME bus workstations. Each hosts a Datum bc635vme synchronized generator, which is fed from a Time Systems Technology Model 6460 IRIG–b generator receiving 5MHz from USNO Master Clock #2.

Redundant time is provided by a TrueTime GPS–VME board in one system, which feeds IRIG–b to a TrueTime VME–SG synchronized generator in the second host. Network Time Protocol (NTP) clock drivers were written for these interfaces.

Tick and tock operate as stratum–1 servers of the NTP network time protocol[3]. Clients exchange timestamp packets with the servers to measure delay, clock offset, and network and operating system dispersion. NTP then corrects the local system clock via step offsets or, more commonly, by slewing the UNIX system clock. The adjtime routine the value of the tick increment to be added to the kernel time variable at each hardware timer interrupt.Frequency and phase offsets of the local server UNIX system clocks from their synchronized generators are measured by NTP at 64–second update intervals.

With this off–the–shelf hardware we keep the servers' system clocks to within 100 microseconds of UTC(USNO). (Other NTP hosts do better than this, but our goal is to synchronize UNIX system clocks to tolerable levels, with a minimum of effort. NTP clients synchronize to a few milliseconds of UTC(USNO), and long–distance clients to tens of milliseconds.

TESTING NTP TIME TRANSFERS

For the past six months we have synchronized to our servers a number of local hosts and one distant source, an HP9000/425t located at the Naval Observatory Time Substation near Miami, FL.To converse with the latter system from Washington, we must route packets through six or seven intervening NASA sites. Pings take from 100 to 3400 ms, depending n the level of net traffic. Yet we are able to do quite satisfactory system time synchronization, as the figures demonstrate.

One measure of the success of network time synchronization is TDEV, the "time domain stability measure" as described by D. W. Allan et. al. at the 1994 Frequency Control Symposium[4]

$$\sigma_x = [1/6 < (\Delta^2 \bar{x})^2 >]^{\frac{1}{2}} \qquad (1)$$

In the following "sigma–tau" diagrams, one is able to distinguish types of noise, decorrelation timescales, and even diurnal modulation of workstation crystal clocks[5].

FUTURE WORK

The success of the USNO network time servers, which are now processing about 155,000 NTP packets per month, establishes them in the ranks of the few stratum–1 servers.But clearly Washington, DC–based servers are of limited usefulness nationally. The growing availability of low–cost GPS receivers, and even integrated, standalone GPS/NTP servers, provides thepotential for an ensemble of geographically dispersed time servers with sources of reliable and accurate time traceable to UTC(USNO) via GPS. It would take only about a dozen GPS/NTP servers, located on the ANSnet T3 backbone, to provide nationwide network time services that would be dependable and accurate[6], and a similar number for the Defense Information Systems Network (DISN).

The USNO will upgrade its Internet link to a T1 line from its present 56kb connection in December, 1994[7]. This should smooth some of the serious time warps seen by our WAN clients. ISDN promises further potential for wide–area timing links. USNO plans to be active in time synchronization via ISDN in 1995.

NETWORK TIME SERVICES

UTC(USNO) is provided over the network via a number of protocols.

1. RFC–1305 NETWORK TIME PROTOCOL
   The USNO time servers are stratum 1 servers for the Network Time Protocol (NTP) [DARPA Network Working Group Report RFC–1305].

2. TELNET ASCII TIME
   The U.S. Naval Observatory Master Clock is accessible in low–precision mode via telnet to one of the time servers on port 13. The time server will ping your system and estimate the network path delay. It will then send Modified Julian Date, Day of Year, and UTC time as ASCII strings followed by an on–time mark (*) which will be advanced by the estimated network delay. The uncertainty in the network delay estimate can reach hundreds of milliseconds, but is typically good to a few tens of milliseconds.

3. RFC 868 TIME PROTOCOL
   The "time" protocol [RFC–868] is supported on TCP and UDP port 37. This service returns a 32–bit binary number, in network byte order, representing the number of seconds of time since 1 Jan. 1900 UT. The "rdate" program uses TCP port 37 and is supported on our servers.

4. RFC 867 DAYTIME PROTOCOL
   The ASCII "daytime" protocol is supported only on UDP port 13. The TCP implementation has been replaced by the telnet ASCII time protocol above.

REFERENCES:

[1] Lottor, Mark, Internet Domain Survey, Oct. 1994

[2] Mills, D.L., Information on NTP Time Servers and Radio Timecode Receivers, 3 Nov. 1994

[3] Mills, D.L., Network time Protocol (Version 3) specification, implementation, and analysis. DARPA Network Working Group Report RFC–1305, University of Delaware, March 1992, 113 pp.

[4] Allan, D. W., Time–Domain Instability Measures in Time and Frequency and for Telecommunications, lecture notes, Frequency and Control Symposium, 1994.

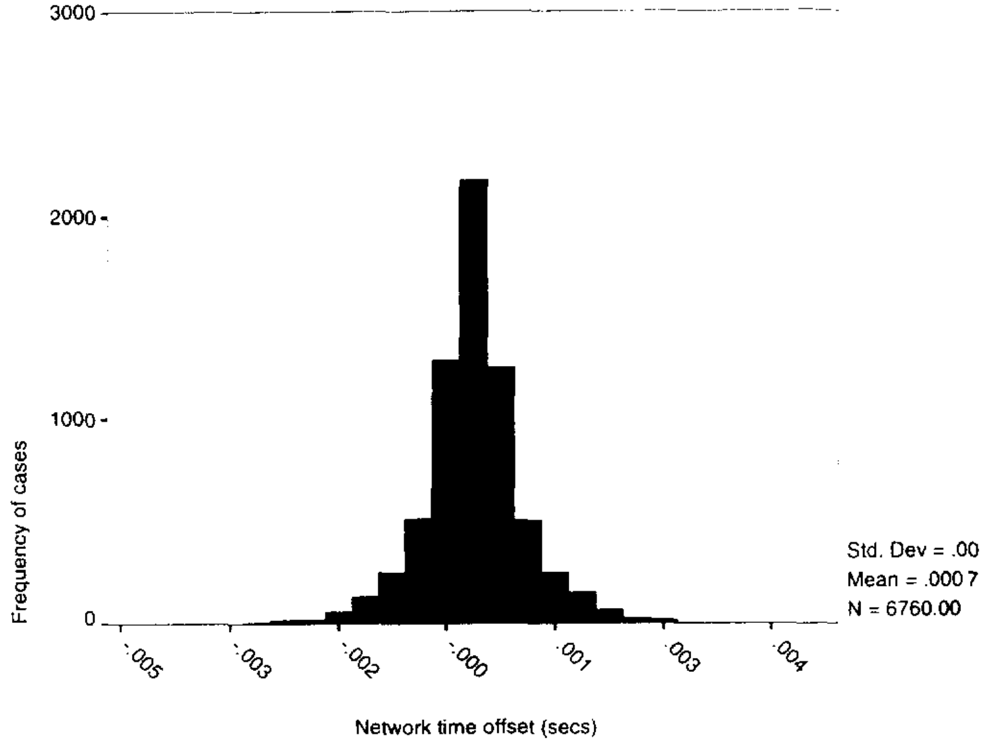
[5] DeYoung, J. A., private communication.

[6] ANSnet T3 Backbone Map, Advanced Network & Services

[7] Withington, F. N., private communication.

NTP Synchronization

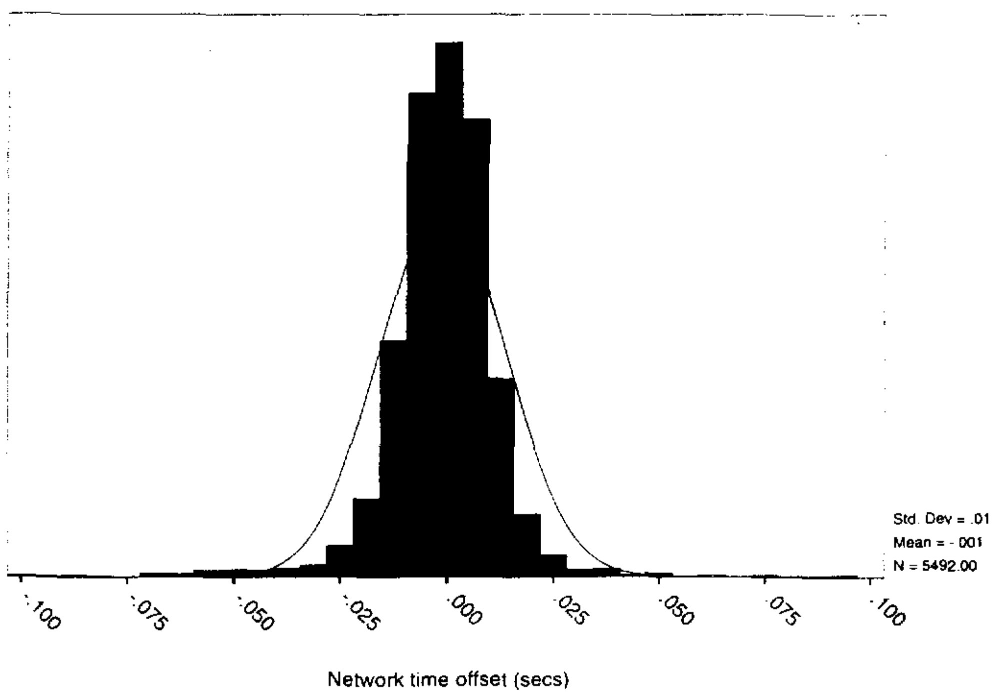
USNO Local LAN



NTP Time Synchronization

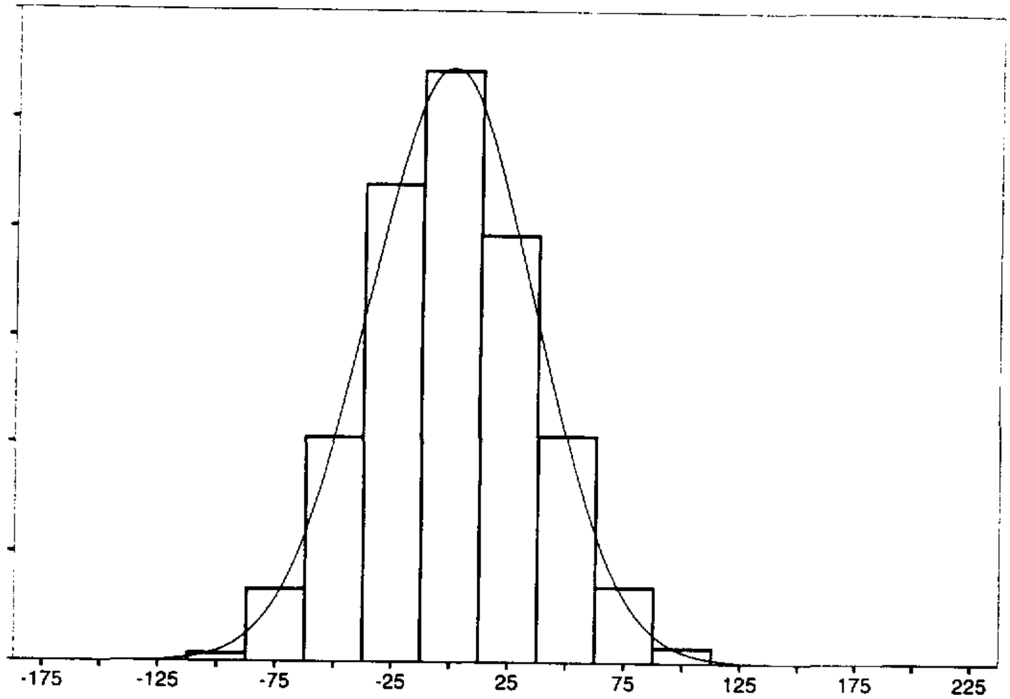
Washington, DC - Miami, FL

Aug. - Nov. 1994



Server Clock - UTC(USNO)

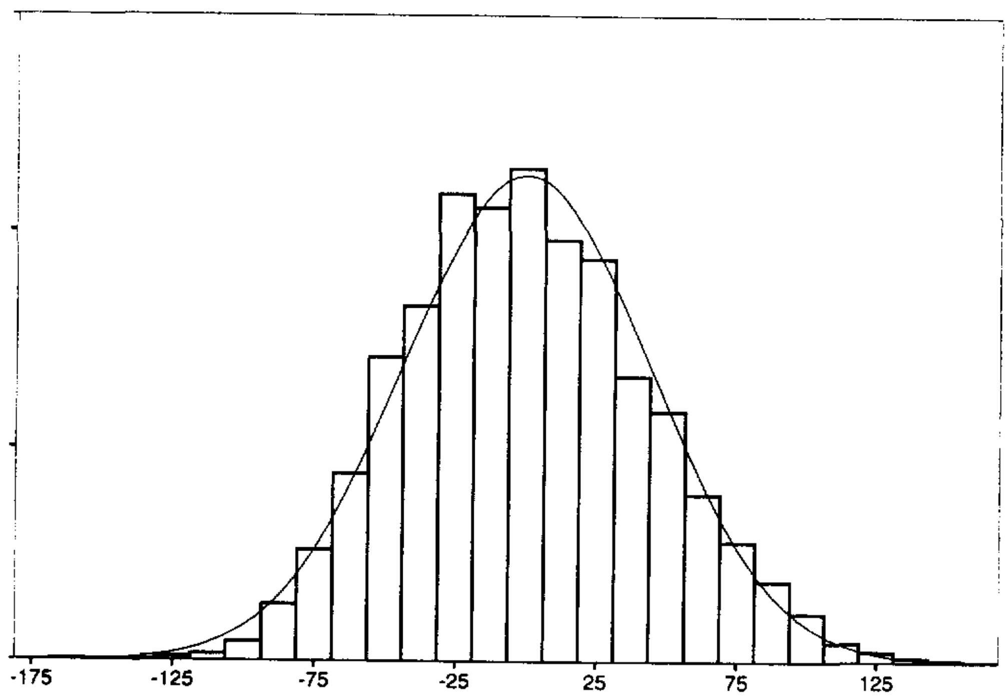
tick.usno.navy.mil



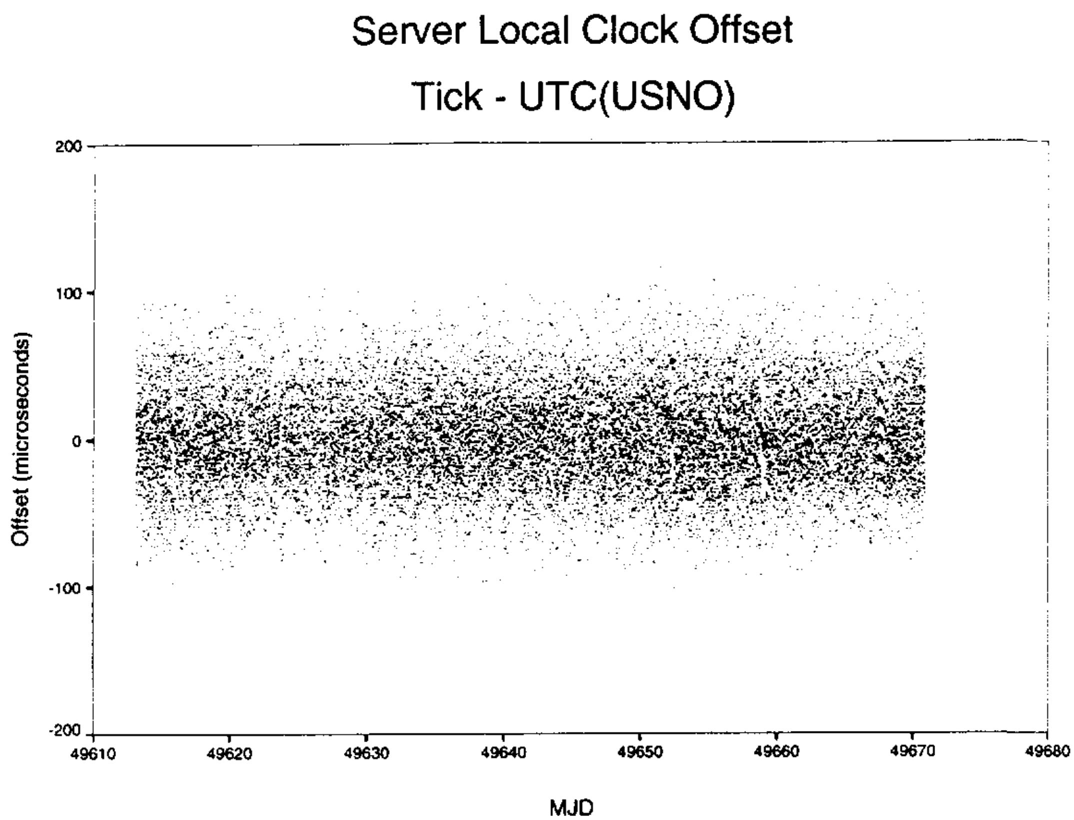
System Clock offset (microseconds)

Server Clock - UTC(USNO)

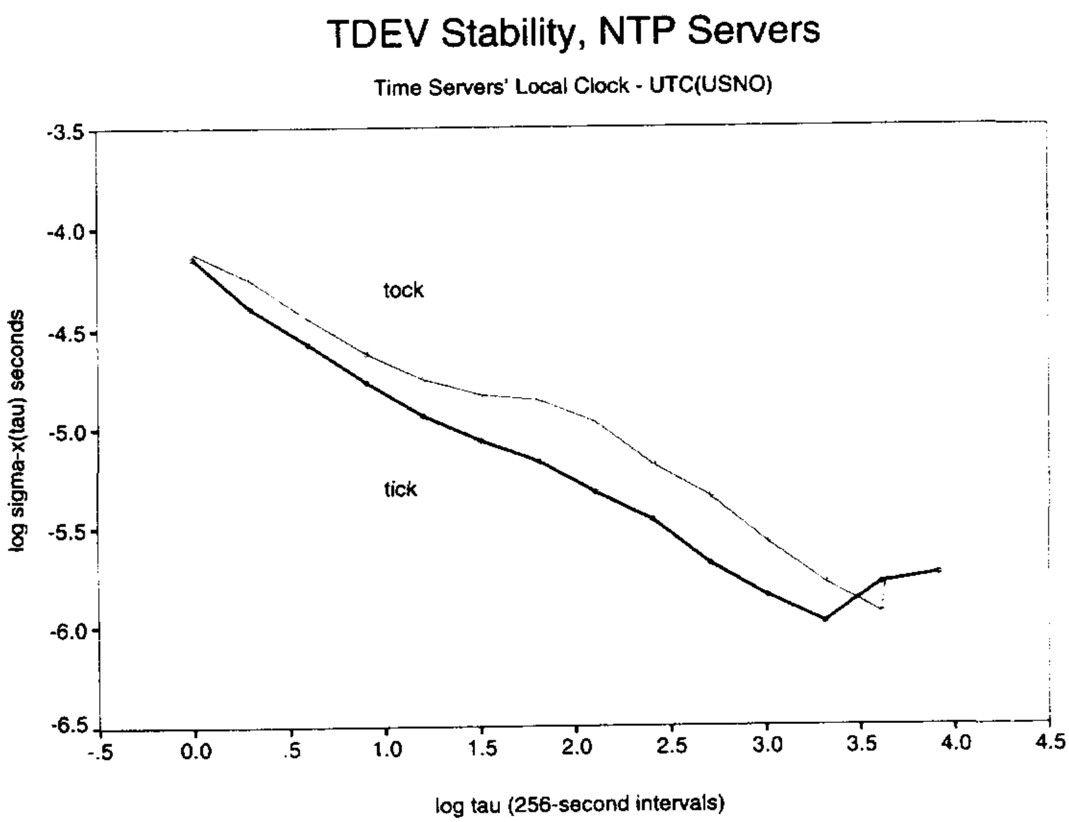
tock.usno.navy.mil



Local clock offset (microseconds)



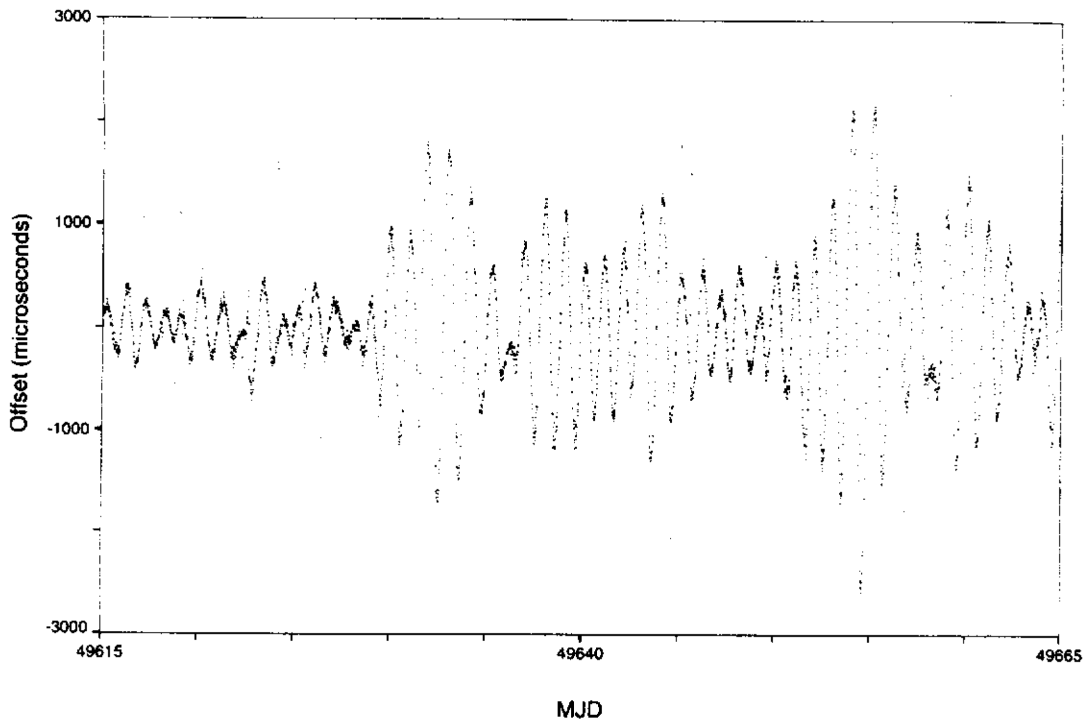
Server Local Clock Offset
Tick - UTC(USNO)
200
100
0
-100
-200
Offset (microseconds)
49610
49620
49630
49640
49650
49660
49670
49680
MJD



TDEV Stability, NTP Servers
Time Servers' Local Clock - UTC(USNO)
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
log sigma-x(tau) seconds
tock
tick
-.5
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
log tau (256-second intervals)

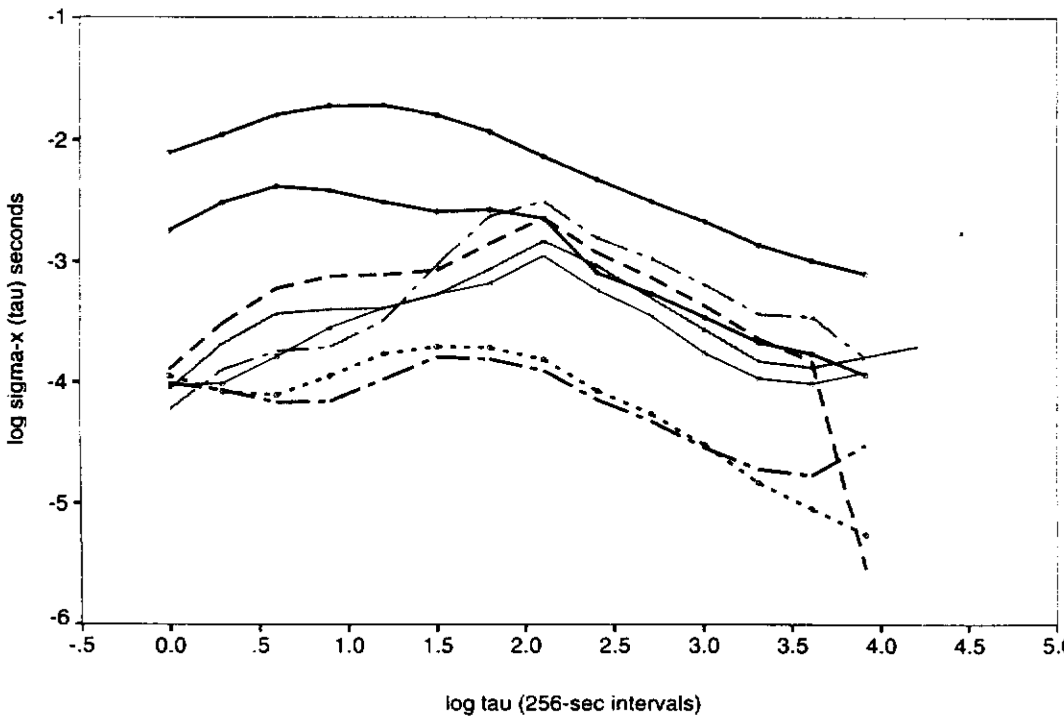
Diurnal Modulation of Local Client

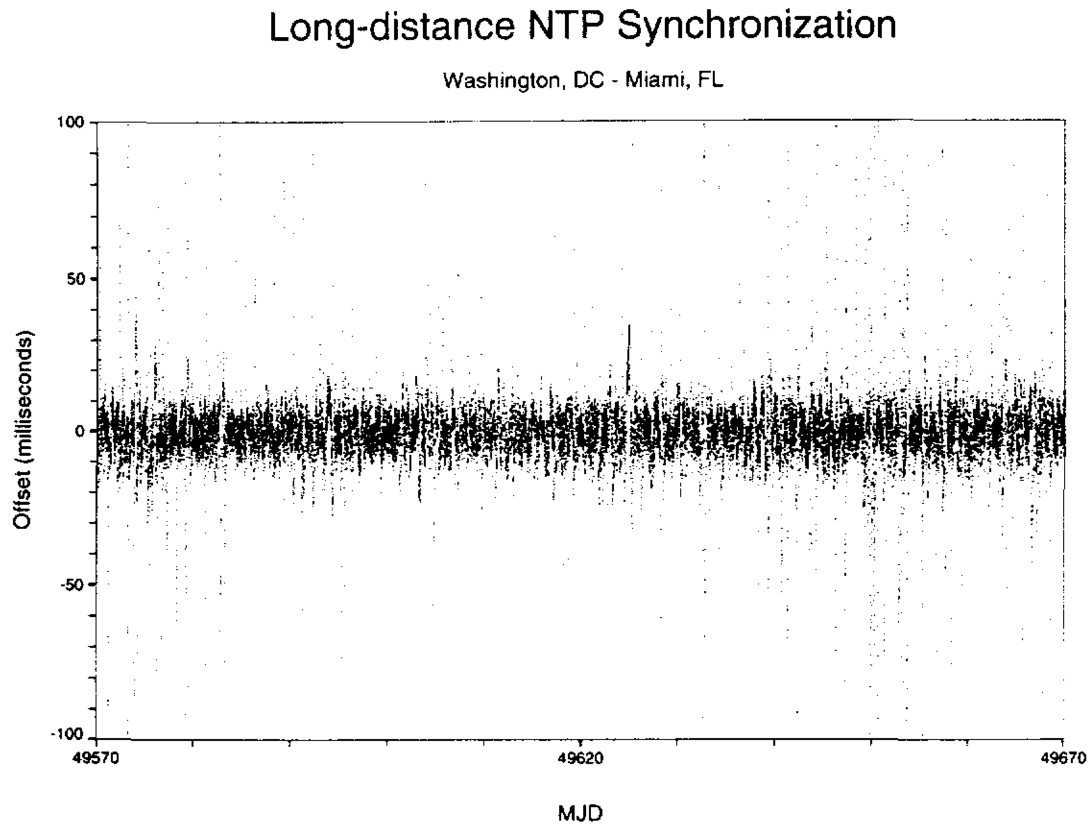
cassini.usno.navy.mil

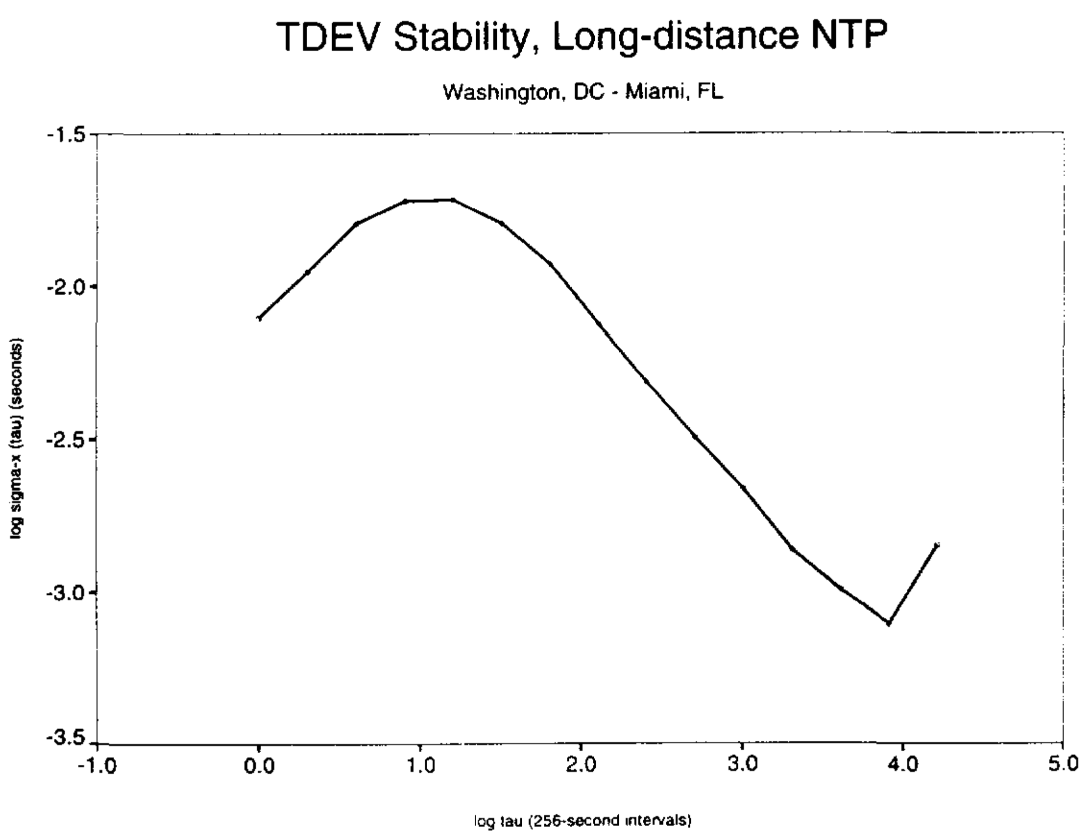


TDEV Stability, NTP Clients

Local USNO Lan Clients




Long-distance NTP Synchronization
Washington, DC - Miami, FL
100
50
0
-50
-100
Offset (milliseconds)
49570
49620
49670
MJD


TDEV Stability, Long-distance NTP
Washington, DC - Miami, FL
-1.5
-2.0
-2.5
-3.0
-3.5
log sigma-x (tau) (seconds)
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
log tau (256-second intervals)